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Incinerability Index: A Measure of Incinerator Performance

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16. ABSTRACT

Since promulgation of the hazardous waste incinerator performance standards in January 1981, there has been a continuing interest in validating a real-time surrogate means of measuring incinerator compliance with the destruction and removal efficiency (DRE) performance standard. One such possible surrogate is sulfur hexafluoride (SF_6). SF_6 is one of the most stable compounds known with respect to thermal decomposition. Thus it has been hypothesized that the SF_6 DRE would represent a lower bound to other principal organic hazardous constituent (POHC) DREs in an incinerator. Further, SF_6 can be measured at very low concentrations in flue gas on a real-time basis using onsite gas chromatographic techniques. Thus, use of SF_6 injection with real-time DRE measurement represents a potentially attractive surrogate DRE measure for determining continuous compliance with the DRE performance standard.

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INCINERABILITY INDEX: A MEASURE OF INCINERATOR PERFORMANCE

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CINCINNATI, OHIO 45268

Incinerability Index: A Measure of Incinerator Performance

Introduction:

Ever since EPA became involved in the regulatory/permitting aspects of hazardous waste incinerators, judging incinerator performance on selected principal organic hazardous constituents (POHCs) has been one of its primary goals. The development of a thermal stability index in which hazardous organic compounds could be ranked according to the destruction difficulty experienced during incineration was a logical way to quantitate incinerator efficiency. A number of ranking methods have been proposed, but enjoyed limited success due to poor correlation with field test data (1). In an attempt to extend the applicability of incinerator combustion efficiency ranking, Dellinger and associates have suggested that there are three basic ways in which hazardous organic compounds degrade. According to the data published (2), volatile organic compounds are more easily destroyed under oxidizing conditions when free radicals like OH are prevalent. The semivolatile compounds are more likely to react when pyrolytic conditions exist and lower concentrations of OH are available. A third group of compounds reacts thermally by bond rupture, and is independent of oxidizing/reducing conditions in the combustion chamber.

During the operation of a typical hazardous waste incinerator, the combustion chamber is capable of producing a wide variety of combustion conditions and duplicating the environment necessary to test the ranking system proposed by Dellinger is difficult. EPA's Offices of Research and Development and Solid Waste have supported the multi-mechanism approach to ranking hazardous organic compounds. Initially, most of the effort was focused on the theoretical aspects of ranking the compounds and the is work was bolstered by some bench scaled ata. The approach and preliminary data were sufficiently encouraging that it was decided to study this concept on a liquid injection pilot scale unit and to compare its results with the data predicted from the bench scale experiments.

Experimental:

The compounds selected for the test mixture were picked to give a wide spectrum of data on combustion efficiency or compound ranking. The volatile compounds were: toluene, tetrachloroethylene and chlorobenzene. The semi-volatile compound was pentachlorobenzene, and sulfur hexafluoride was added as a tracer and indicator compound for the bond rupture mechanism. The composition of the test mixture is shown in Table 1.

The organic compounds were mixed together to make a standard solution, and were injected into the incinerator at a constant rate throughout the tests. The sulfur hexafluoride was a gas and was injected onto the synthetic mixture just prior to incineration.

The incinerator operating parameters were varied during this set of tests centered around temperature and oxygen concentration in the primary combustion chamber. As these parameters were varied, the gas stream was sampled at the secondary combustion chamber outlet and analyzed for the specific compounds (with EPA methodology), and the results expressed in terms of destruction removal efficiency (DRE). Table 2 illustrates the planned test variable matrix used for

this experiment.

Table 1. Incinerator Index Test Mixture

Component	Mixture Weight (percent)	Approximate Ultimate Analysis (weight percent) C	H	Cl	F	S	Heating Value (Btu/lb)	Specific Gravity
Toluene	70.1	91.3	8.7				18,270	0.87
Chlorobenzene	10.0	64.0	4.4	31.6			11,890	1.31
Perchloroethylene	10.0	14.5		85.5			2,140	1.11
Tetrachloroethylene	9.9	28.7	0.4	70.9			6,390	1.83
SF_6	0.1				78.1	21.9	100[a]	--
Calculated Test Mixture	100.0	74.6	6.6	18.7	0.1	0.02	14,560	1.03

[a]Estimated

Table 2. Test Variable Matrix

Test Point	Primary Combustor Temperature (^oF)	Primary Combustor Exit Flue Gas O_2 (percent)	Expected Flowrates Test Mixture (gph)	Propane (scfh)	Burner Air (scfh)	Flue Gas (scfh)	Calculated Primary Combustor Residence Time (sec)
1	1,720	1.5	1.46	0	1,890	1,890	36
2	2,000	0.0	1.46	6	1,910	2,010	31
3	1,600	5.0	1.46	7	2,510	2,610	29
4	2,280	1.5	1.46	28	2,610	2,750	20
5	2,000	5.0	1.46	35	3,360	3,520	18
6	1,720	8.5	1.46	50	4,850	5,040	14
7	2,400	5.0	1.46	91	5,090	5,350	10
8	2,000	10.0	1.46	253	14,380	14,970	4.2
9	2,280	8.5	1.46	295	14,360	15,020	3.8
10	2,000	5.0	1.46	35	3,360	3,520	18

EPA operates an experimental facility in Jefferson, Arkansas, and one of its many functions is to evaluate the thermal treatment of hazardous waste. This was the facility chosen to conduct the pilot scale test on the ranking index for the incineration of hazardous compounds. The CRF is a 3100-ft^2 facility (in the process of becoming a 12,400-ft^2 facility) in which there are two pilot-scale incinerators on site - a rotary kiln incinerator system (RKS) and a liquid injection incinerator system (LIS). The liquid injection incineration system consists of a primary combustion chamber, an unfired afterburner, and a primary air pollution control system consisting of a quench Chamber, packed column scrubber, and ionizing wet scrubber.

Figure 1 is a schematic diagram of the liquid injection incineration system.

Results:

The data collected on the DRE for all the different POHC compounds vs. temperature was summarized in Figure 2. This busy illustration can be simplified by examining the DRE of the individual compounds vs. operating temperature in the kiln. Figures 3 through 6 illustrate the effect of temperature on individual DRE and show little or no statistical correlation. The correlation coefficient for each regression analysis is shown in Table 3.

Table 3. Regression Analysis Correlation Coefficient

Compound	Correlation Coefficient
Pentachlorobenzene	0.002
Chlorobenzene	0.005
Toluene	0.016
Tetrachloroethylene	0.142

The sulfur hexafluoride was the compound selected for monitoring the bond rupture component of the proposed index, and should be dependent on temperature. Figure 7 shows the SF_6 DRE as a function of operating temperature. A trend toward increasing SF_6 is observed with increasing temperature. If the SF_6 DRE values are averaged around the 5 general temperature areas experienced in the test, the relationship illustrated in Figure 8 is produced. The relationship shows a better linear relationship between SF_6 and temperature, and its supports the idea that SF_6 is destroyed by bond rupture.

In addition to temperature data, the DRE for all the test compounds were compared with the oxygen concentrations measured in the kiln. These data were summarized in Figure 9 and were very similar to the temperature data presented in Figure 2. To simplify the data, the individual compound's DRE were compared with the average oxygen concentration determined during the test period. Figures 10 through 12 show the DRE vs O_2 relationships for the volatile compounds. The slope of the curve and the correlation coefficients are shown in Table 4.

Table 4. Slope and Regression Analysis Coefficients

Compound	Correlation Coefficient	Slope
Chlorobenzene	0.033	0.050
Toluene	0.092	0.071
Tetrachloroethylene	0.495	0.144

If the relationships proposesd are valid, there should be a correlation between the oxygen concentration and the extent to which the volatile compounds are destroyed. It appears that there is no significant statistical linear

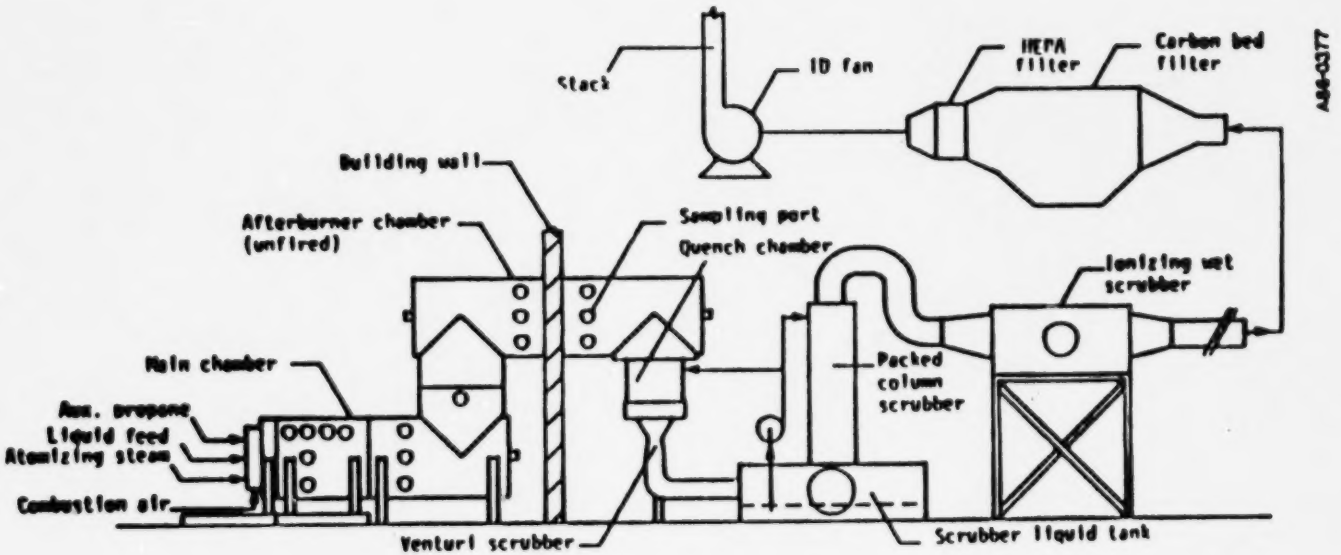


Figure 1. Simplified schematic of the EPA CRF liquid injection incinerator system.

FIGURE 2

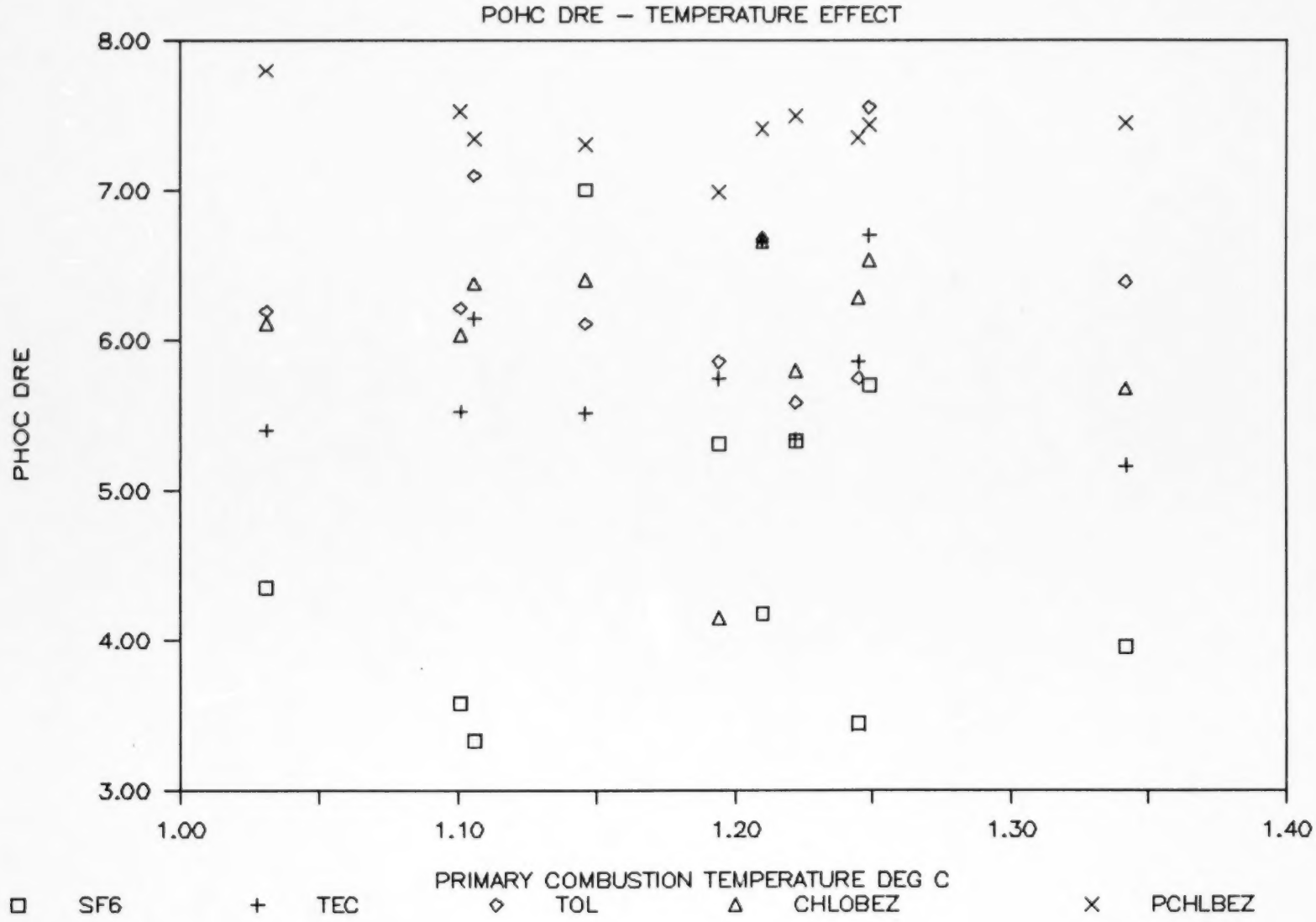

POHC DRE – TEMPERATURE EFFECT
8.00
7.00
6.00
5.00
4.00
3.00
PHOC DRE
1.00
1.10
1.20
1.30
1.40
PRIMARY COMBUSTION TEMPERATURE DEG C
SF6
TEC
TOL
CHLOBEZ
PCHLBEZ

FIGURE 3

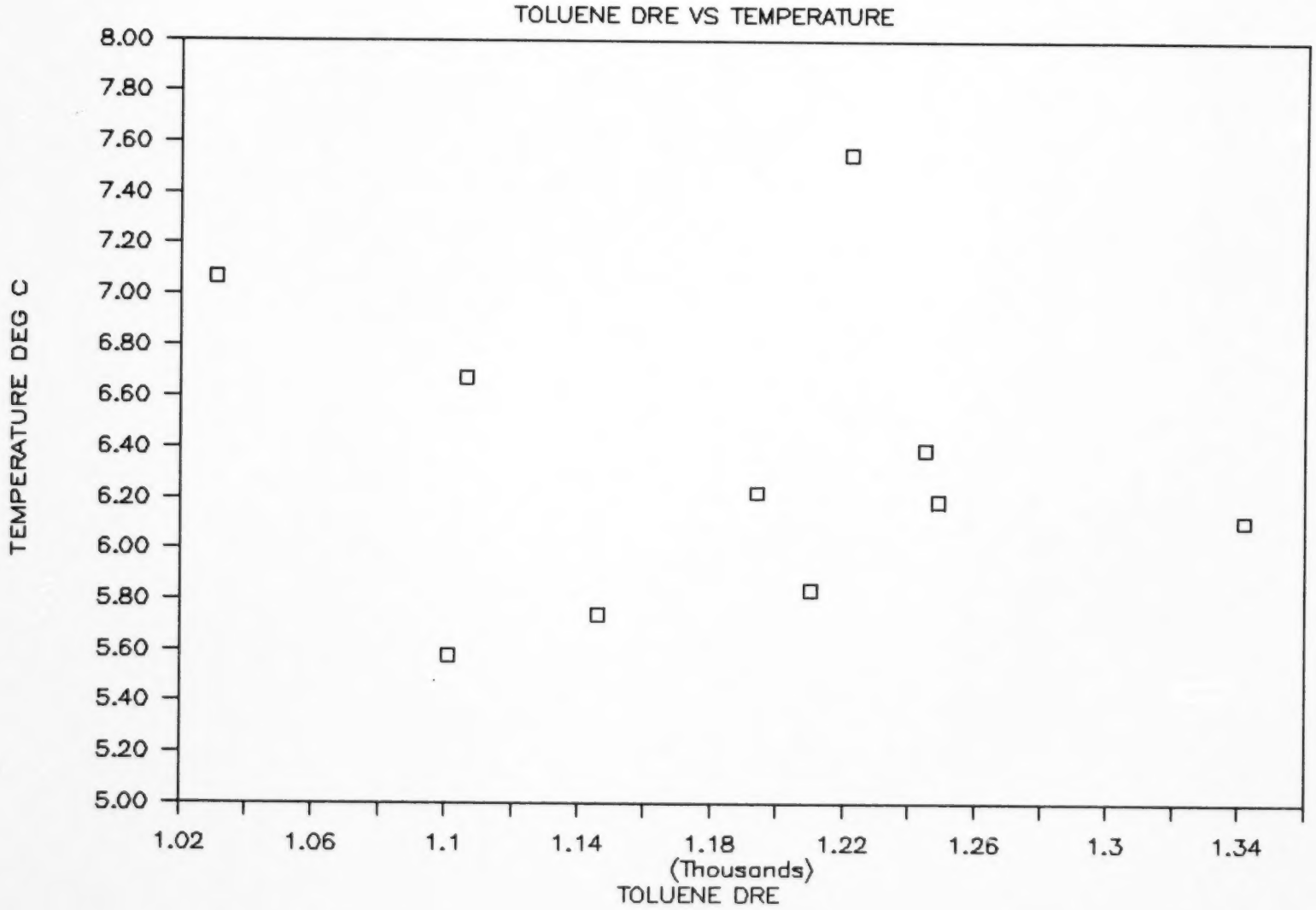

TOLUENE DRE VS TEMPERATURE
TEMPERATURE DEG C
8.00
7.80
7.60
7.40
7.20
7.00
6.80
6.60
6.40
6.20
6.00
5.80
5.60
5.40
5.20
5.00
1.02
1.06
1.1
1.14
1.18
1.22
1.26
1.3
1.34
(Thousands)
TOLUENE DRE

FIGURE 4

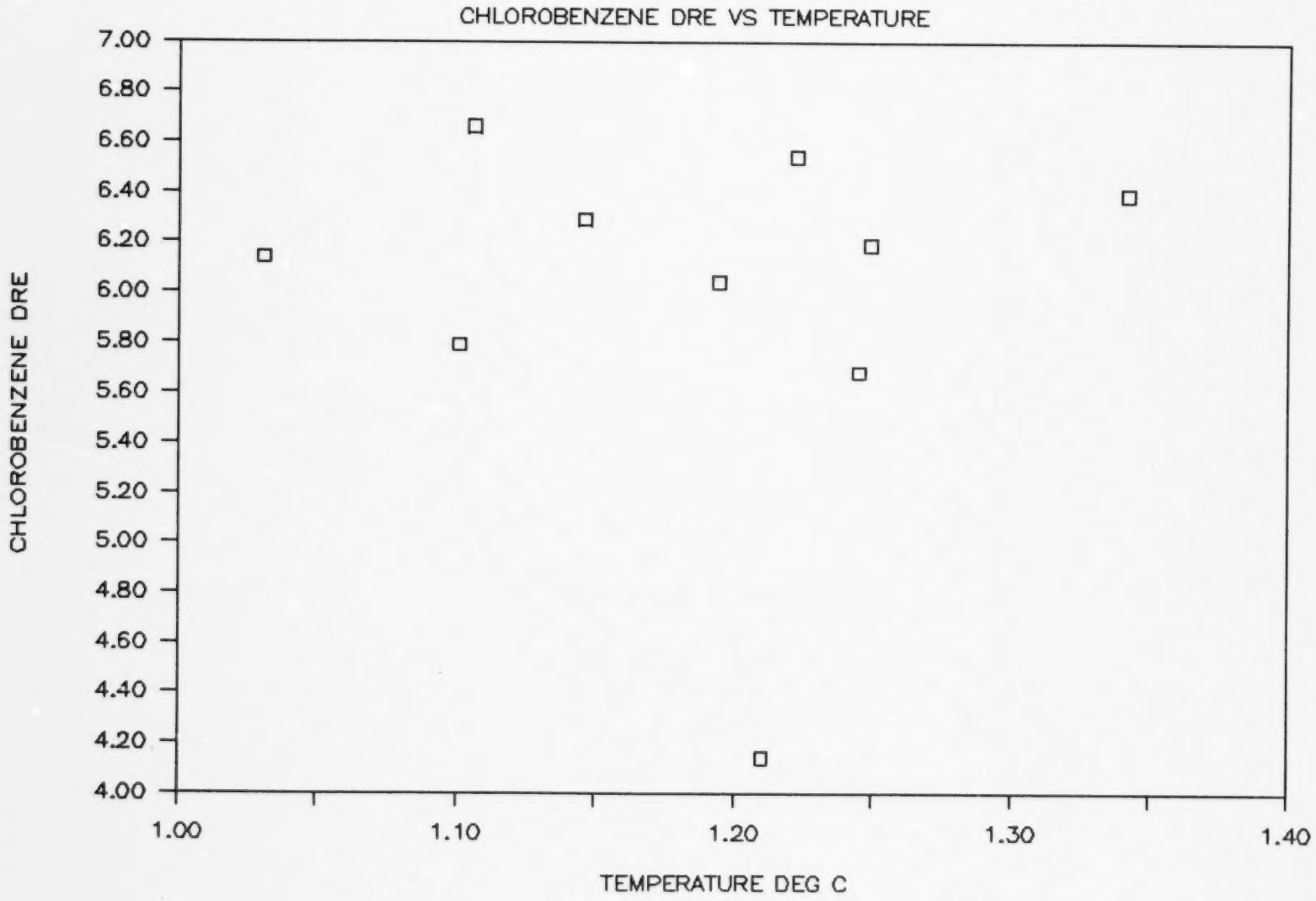

CHLOROBENZENE DRE VS TEMPERATURE
CHLOROBENZENE DRE
7.00
6.80
6.60
6.40
6.20
6.00
5.80
5.60
5.40
5.20
5.00
4.80
4.60
4.40
4.20
4.00
1.00
1.10
1.20
1.30
1.40
TEMPERATURE DEG C

FIGURE 5

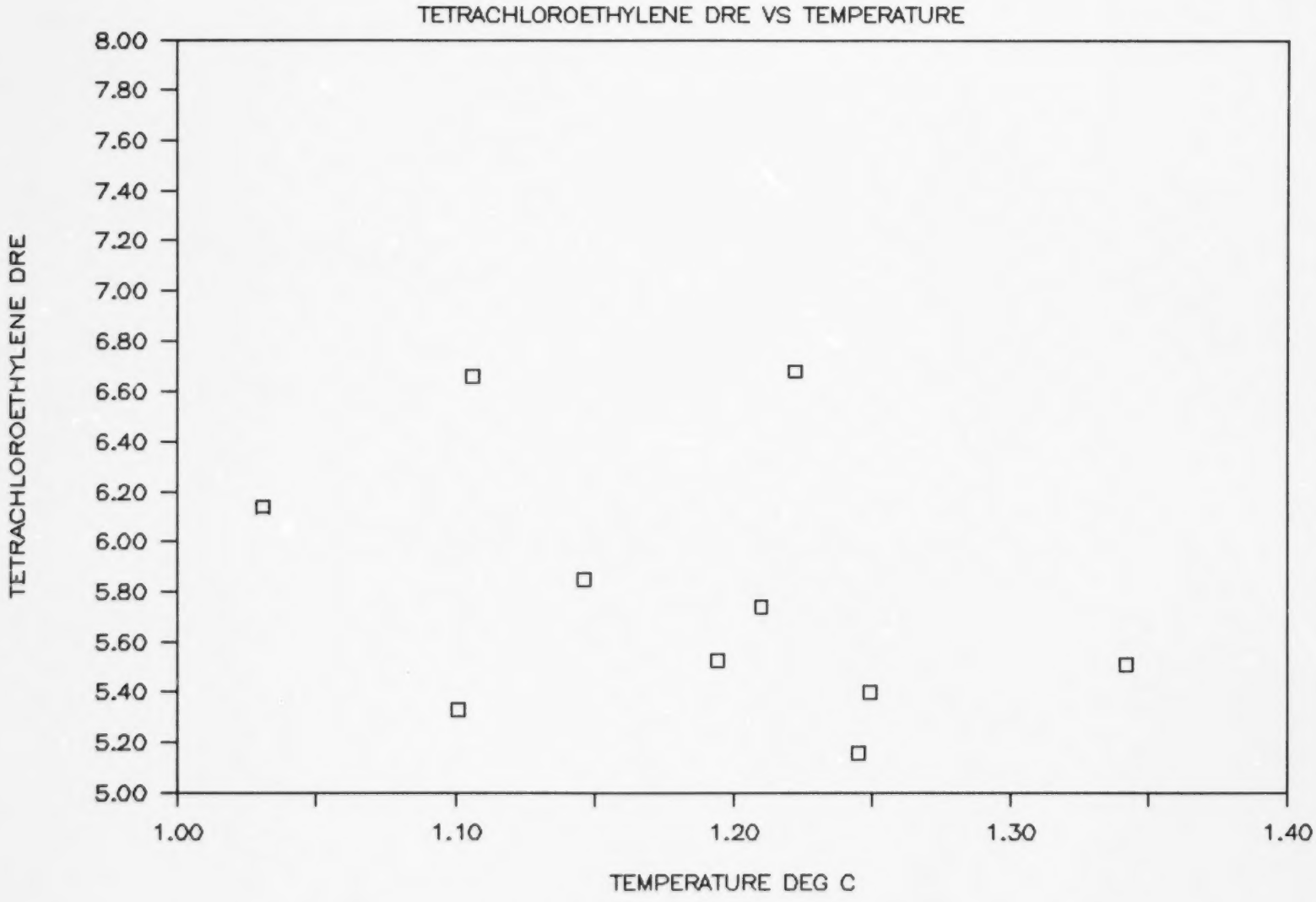

TETRACHLOROETHYLENE DRE VS TEMPERATURE
TETRACHLOROETHYLENE DRE
8.00
7.80
7.60
7.40
7.20
7.00
6.80
6.60
6.40
6.20
6.00
5.80
5.60
5.40
5.20
5.00
1.00
1.10
1.20
1.30
1.40
TEMPERATURE DEG C

FIGURE6

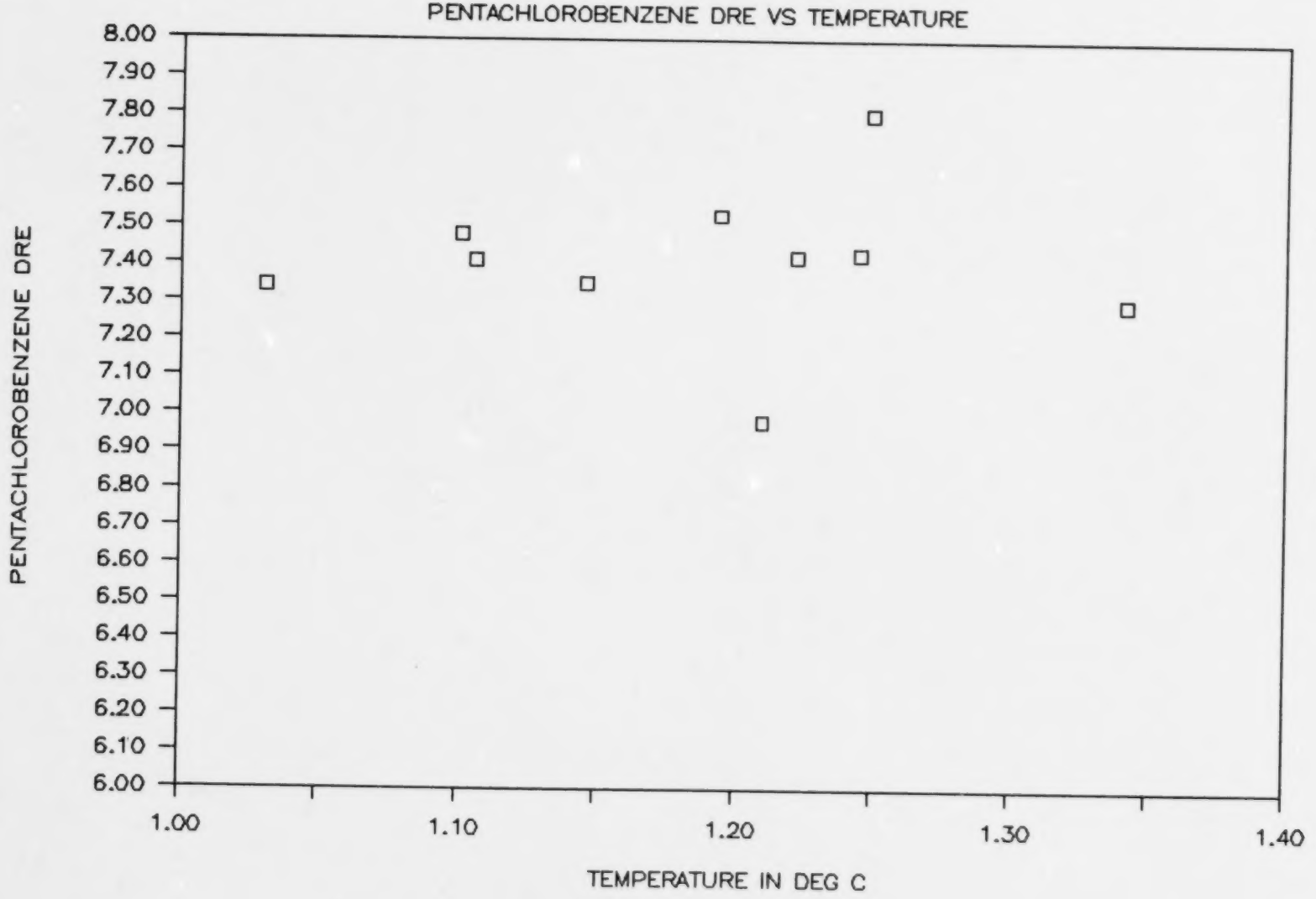

PENTACHLOROBENZENE DRE VS TEMPERATURE
PENTACHLOROBENZENE DRE
8.00
7.90
7.80
7.70
7.60
7.50
7.40
7.30
7.20
7.10
7.00
6.90
6.80
6.70
6.60
6.50
6.40
6.30
6.20
6.10
6.00
1.00
1.10
1.20
1.30
1.40
TEMPERATURE IN DEG C

FIGURE7

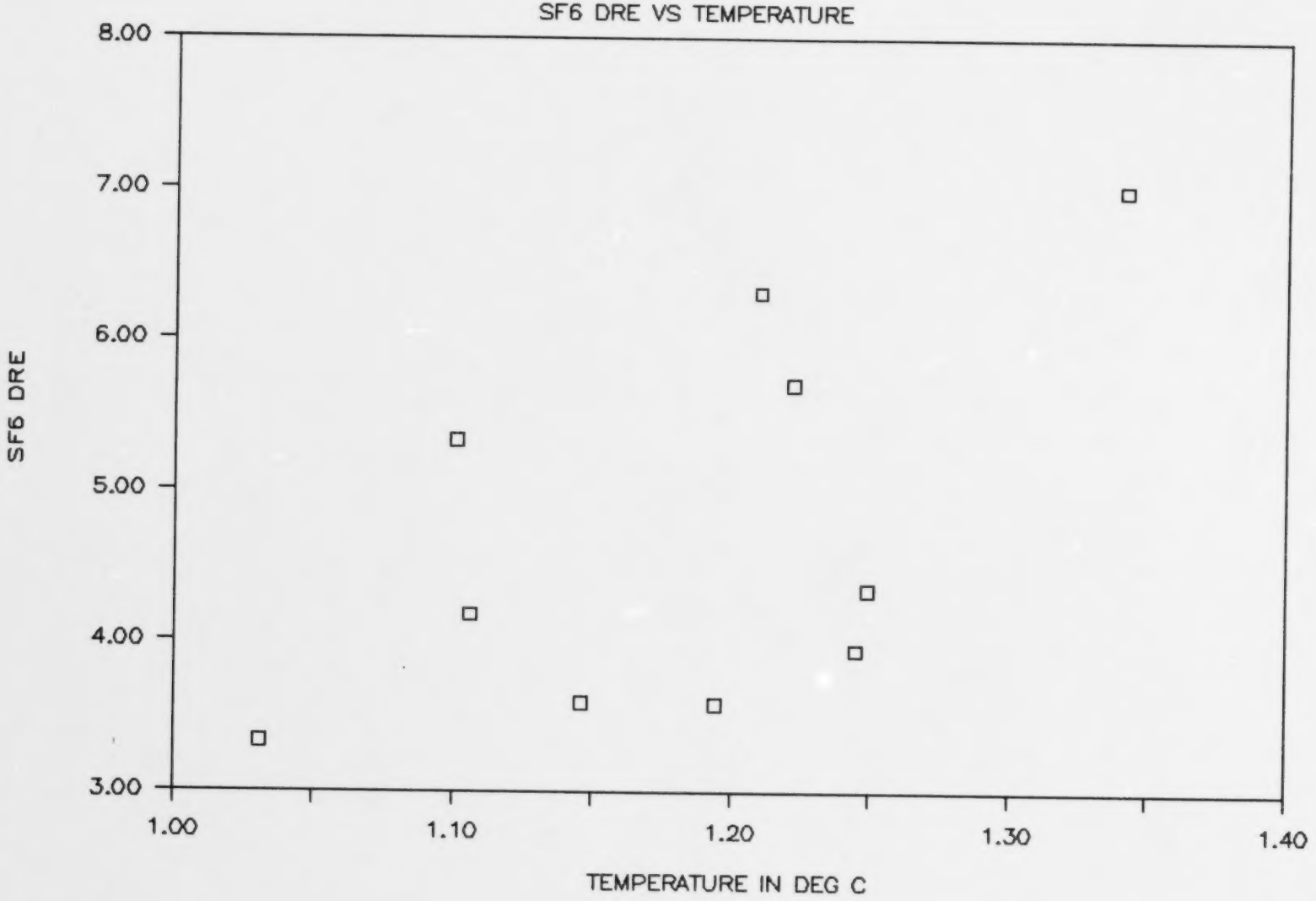

SF6 DRE VS TEMPERATURE
8.00
7.00
6.00
5.00
4.00
3.00
SF6 DRE
1.00
1.10
1.20
1.30
1.40
TEMPERATURE IN DEG C

FIGURE 8

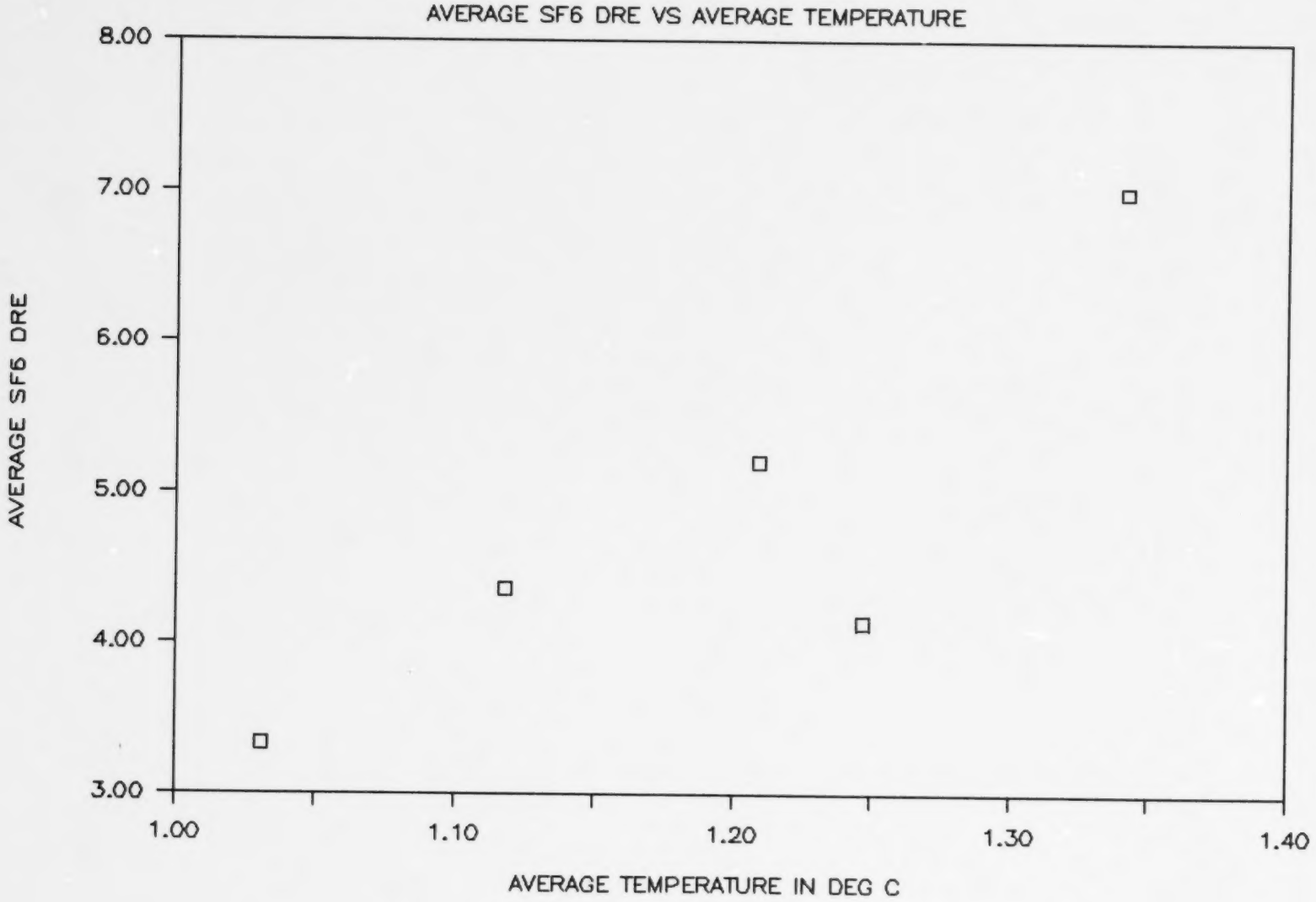

AVERAGE SF6 DRE VS AVERAGE TEMPERATURE
8.00
7.00
6.00
5.00
4.00
3.00
AVERAGE SF6 DRE
1.00
1.10
1.20
1.30
1.40
AVERAGE TEMPERATURE IN DEG C

FIGURE 9

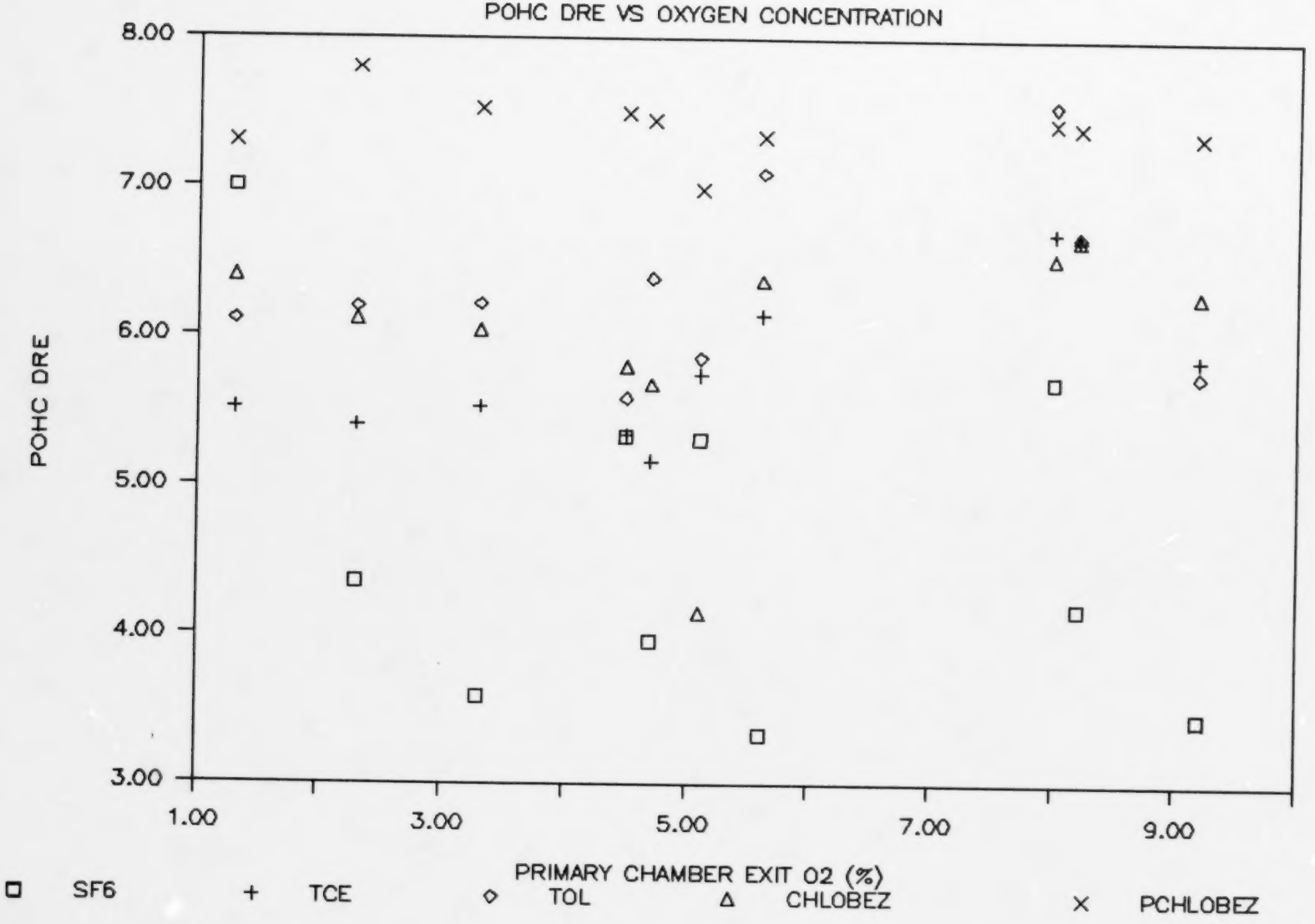

POHC DRE VS OXYGEN CONCENTRATION
8.00
7.00
6.00
5.00
4.00
3.00
POHC DRE
1.00
3.00
5.00
7.00
9.00
PRIMARY CHAMBER EXIT 02 (%)
SF6
TCE
TOL
CHLOBEZ
PCHLOBEZ

FIGURE 10

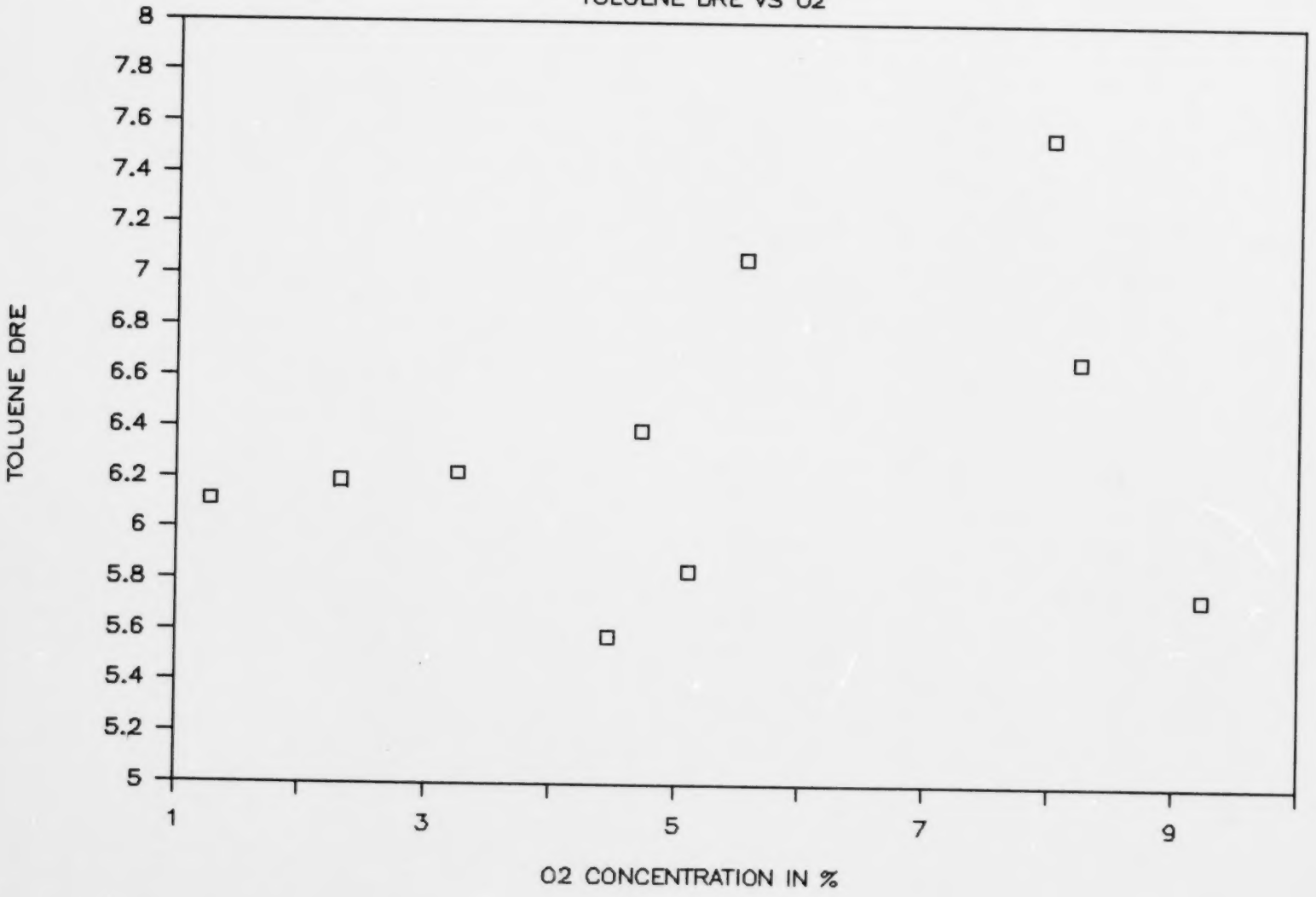

TOLUENE DRE VS 02
TOLUENE DRE
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1
3
5
7
9
02 CONCENTRATION IN %

FIGURE 11

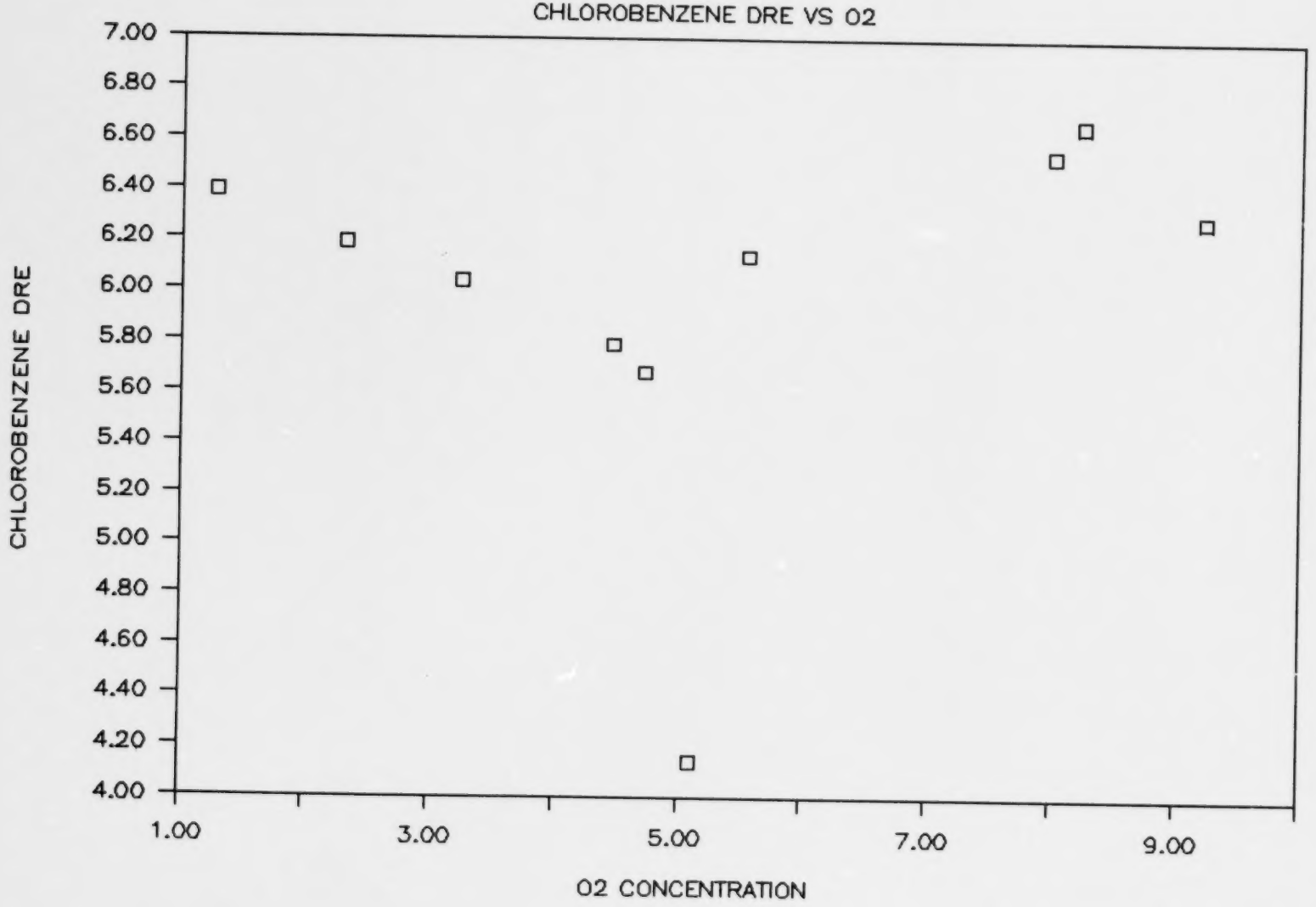

CHLOROBENZENE DRE VS 02
CHLOROBENZENE DRE
7.00
6.80
6.60
6.40
6.20
6.00
5.80
5.60
5.40
5.20
5.00
4.80
4.60
4.40
4.20
4.00
1.00
3.00
5.00
7.00
9.00
02 CONCENTRATION

FIGURE 12

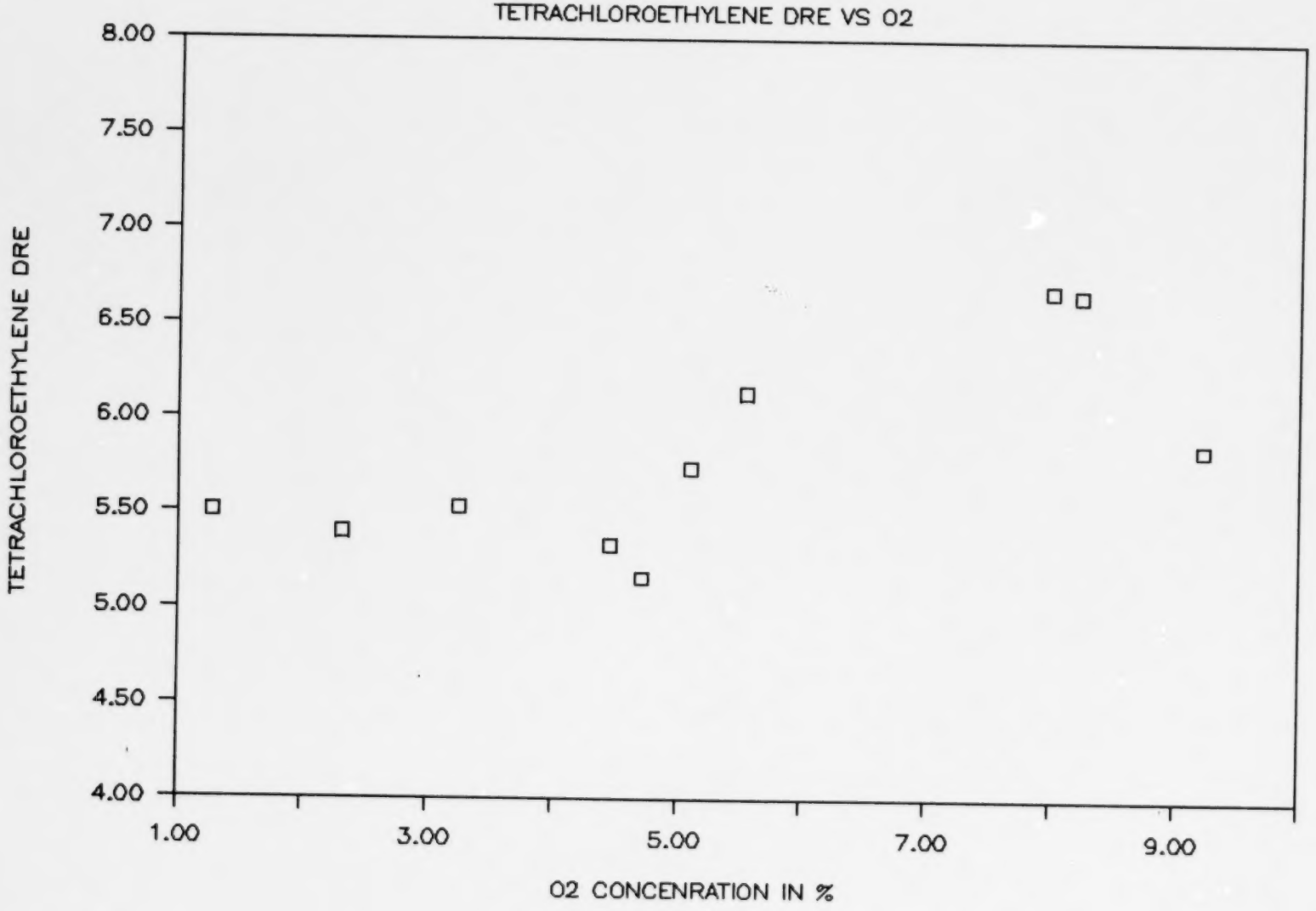
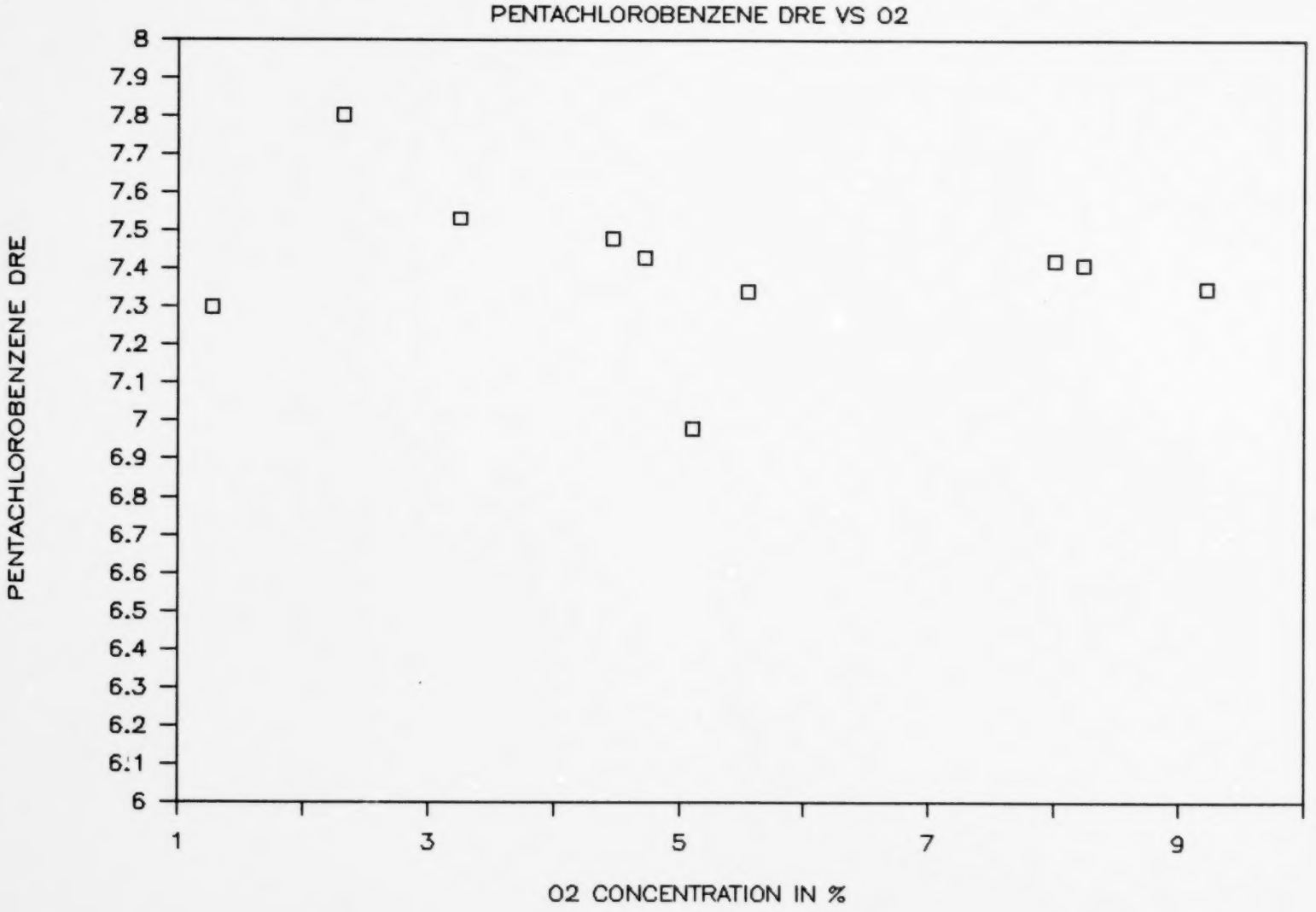

TETRACHLOROETHYLENE DRE VS 02
TETRACHLOROETHYLENE DRE
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
1.00
3.00
5.00
7.00
9.00
02 CONCENRATION IN %

FIGURE 13


PENTACHLOROBENZENE DRE VS 02
PENTACHLOROBENZENE DRE
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6
1
3
5
7
9
02 CONCENTRATION IN %

correlation between the DREs for chlorobenzenes and toluene with oxygen concentration. There does however appear to be a relationship between the tetrachloroethylene and oxygen.

The semivolatile compounds were identified in theory as being more stable under oxygen poor conditions, and the data for pentachlorobenzene desruction vs. O_2 was compiled in Figure 13. As with the volatiles, the pentachlorobenzene did not show a significant statistical correlation of DRE with oxygen concentration.

The data for SF_6 DRE was also summarized as a function of oxygen concentration, and is presented in Figure 14. The large amount of scatter and the poor correlation coefficient indicates that SF_6 reacts independently of oxygen concentration, and supports the unimolecular thermal decomposition aspects of the indexing theory.

The comparison of the individual POHC DREs to operating parameters like temperature and oxygen did not yield the direct correlations that were desired. However, the comparison of the POHC DREs against SF_6 DRE gave some interesting results. Figure 15, is a comparison of the individual POHC DREs plotted against the DRE for SF_6. In greater than 93% of the test data, the individual POHC DRE was greater than the SF_6 DRE, and for cases in which SF_6 DRE was maintained at 99.99, all the POHC DREs were greater than 99.99.

Discussion and Conclusions

The incineration of hazardous waste is a very complex process with numerous chemical reactions taking place simultaneously. EPA has undertaken the difficult task of trying to quantitate the performance of hazardous waste incinerators, and it appears that the approach of trying to correlate individual compound DREs with operating conditions does not work very well. All of the DRE data collected for volatiles and semivolatiles had very low correlation coefficients for the temperature and oxygen variables.

The approach of using SF_6 as a surrogate POHC showed more promise. It appears that SF_6 destruction is dependent on temperature, and independent of oxygen concentration. Some additional work on SF_6 thermal destruction is necessary to substantiate these findings and improve on the precision of the technique. Also, the use of SF_6 as a surrogate/tracer compound was illustrated in these tests. If it can be shown that SF_6 has a consistently low DRE when compared to other POHCs, the possible use of it as a standard surrogate compound in test burns or compliance testing will be greatly enhanced.

FIGURE 14

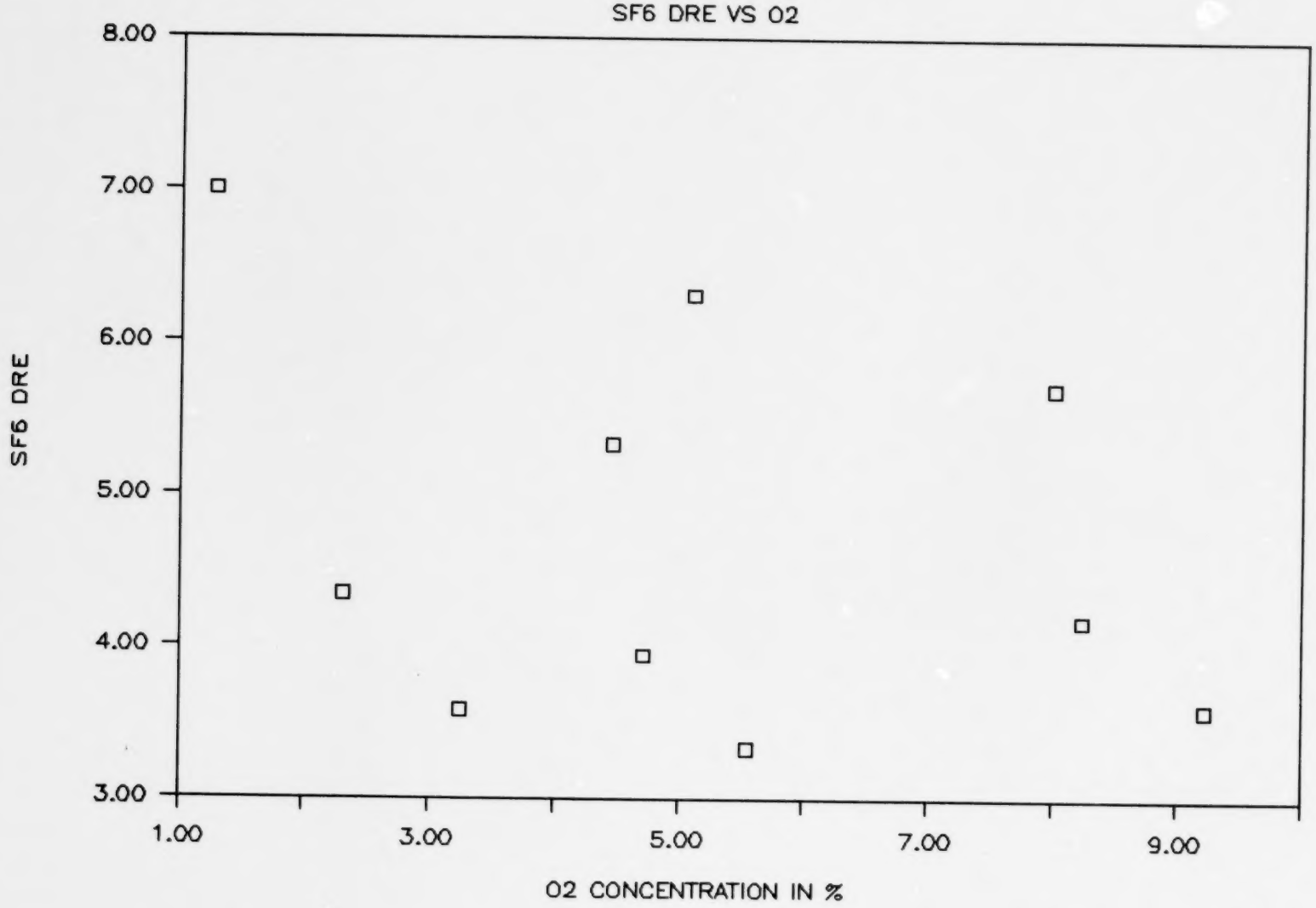
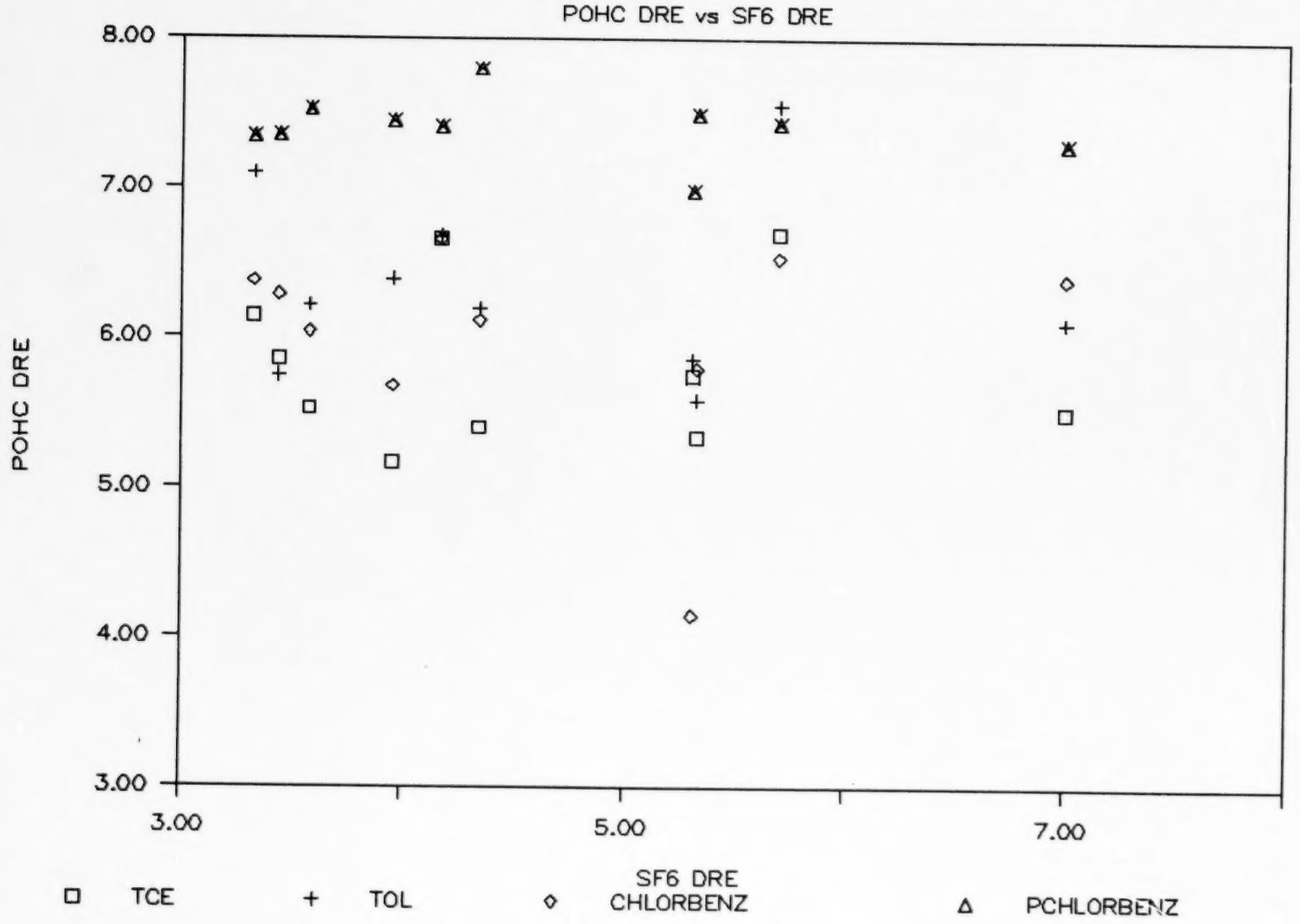

SF6 DRE VS 02
8.00
7.00
6.00
5.00
4.00
3.00
SF6 DRE
1.00
3.00
5.00
7.00
9.00
02 CONCENTRATION IN %

FIGURE 15


POHC DRE vs SF6 DRE
8.00
7.00
6.00
5.00
4.00
3.00
POHC DRE
3.00
5.00
7.00
SF6 DRE
TCE
TOL
CHLORBENZ
PCHLORBENZ

References

1. Dellinger, B., M. Graham, D. Tirey. "Predicting emissions from the thermal prcessing of hazardous wastes." Hazardous Waste and Hazardous Materials. 3: 293-307, (1986).

2. Graham, G., D. Hall and B. Dellinger. "Laboratory investigation of thermal degradation of a mixture of hazardous organic compounds." Environ. Sci. Technol. 20: 7, (1986) p. 703-710.